MULTIMEDIA UNIVERSITY

STUDENT ID NO

MULTIMEDIA UNIVERSITY

FINAL EXAMINATION

TRIMESTER 2, 2016/2017

EEL1206 – INTRODUCTION TO MACHINES AND POWER SYSTEMS

(EE, CE, MCE, ME, TE, OPE, NT)

24 FEBRUARY 2017
9.00 a.m – 12.00 p.m
(3 Hours)

INSTRUCTIONS TO STUDENTS

1. This question paper consists of 8 pages including the cover page and Appendix. There are **FOUR** questions in this paper.

2. Attempt **ALL** questions. All questions carry equal marks and the distribution of marks for each question is given.

3. Some useful formulae are given in the Appendix section.

4. Please write all your answers in the Answer Booklet provided.

Question 1

(a) Define torque. State two differences between a torque and a force.

[4 marks]

(b) The wire shown in Figure Q1(a) is moving in the presence of a magnetic field. With the information given in the figure, determine the magnitude and direction of the voltage induced in the wire.

[4 marks]

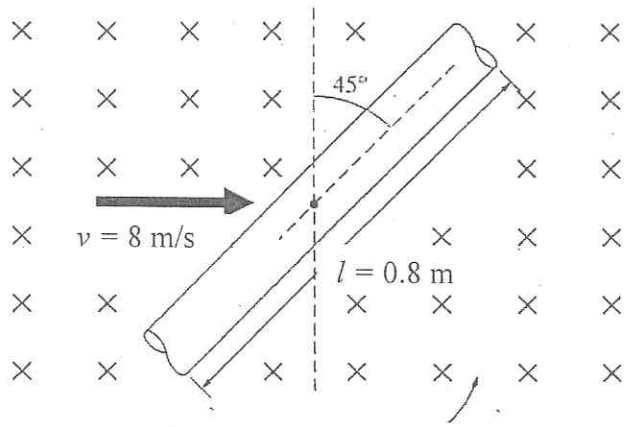

Figure Q1(a)

(c) A motor is supplying 40N-m of torque to its load. If the shaft of the motor is turning at 1600r/min, determine the mechanical power supplied to the load in watts and in horsepower.

[3 marks]

(d) Draw a diagram showing a Δ-Δ three-phase connection system. State the relationship between phase and line quantities for both voltage and current.

[6 marks]

(e) Figure Q1(b) shows a three-phase system connected to a balanced load with an impedance of (8+j15)Ω per phase and a transmission line impedance of (0.2+j0.1)Ω per phase. Assuming $V_{an} = 120\angle 20°$V and the voltage drop across Z_L is negligible small, find:

i. the current I_{aA}, I_{bB} and I_{cC}.

[4 marks]

ii. the total real power P_T, reactive power Q_T, and apparent power S_T.

[4 marks]

Continued...

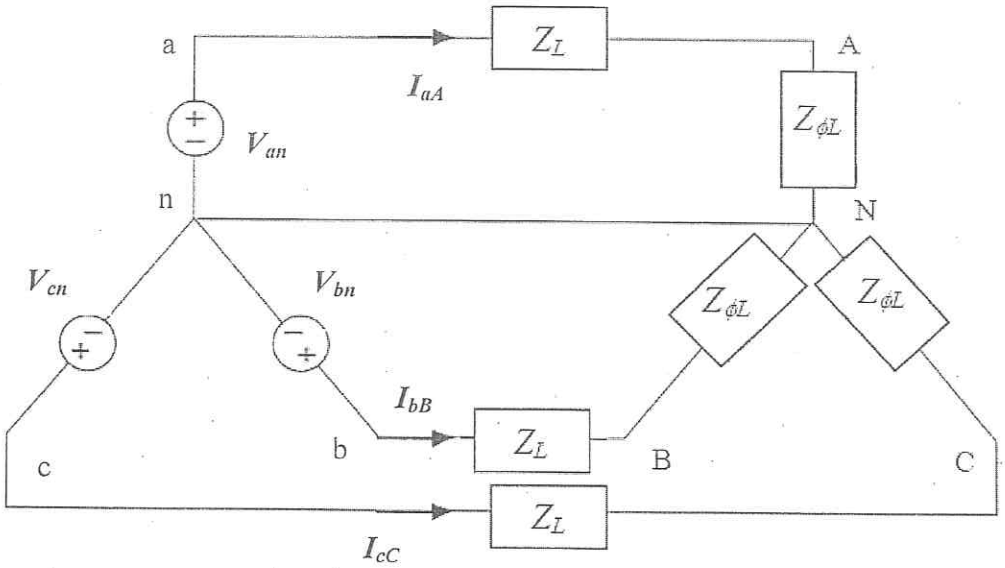

Figure Q1(b)

Continued...

Question 2

(a) Give 3 examples of special transformers and briefly explain their usage.

[6 marks]

(b) Given the primary and secondary windings of 250 and 400 turns respectively, primary voltage of 130V and primary current of 3A, determine the secondary voltage and current of the transformer.

[3 marks]

(c) A single-phase distribution tranformer rated at 20kVA 8000/277V shown in Figure Q2 has the following parameters:

R_p=30Ω R_s=0.1Ω R_c=200kΩ

X_p=50Ω X_s=0.2Ω X_m=25kΩ

i. Draw the exact equivalent circuit of this transformer referred to the primary side. [3 marks]

ii. Draw the exact equivalent circuit of this transformer referred to the secondary side. [4 marks]

Wherever applicable, show your calculation of R_p', R_s', R_c', X_p', X_s' and X_m'.

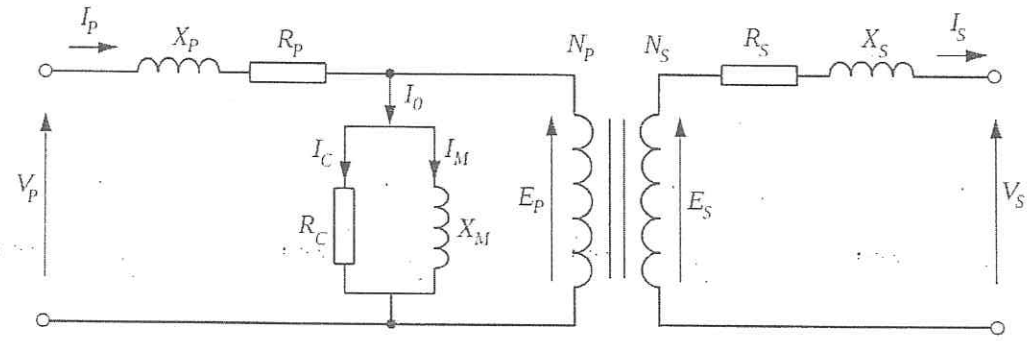

Figure Q2

(d) The transformer in (c) is supplying rated load at 277V at 0.75 power factor lagging. By using the exact equivalent curcuit, determine the following:

i. The secondary current I_s and I_s'.

[2 marks]

ii. The voltage regulation VR of the transformer.

[3 marks]

iii. Assuming the primary winding's copper loss is 320W, calculate the efficiency η of the transformer.

[4 marks]

Continued...

Question 3

(a) Describe the characteristic of magnetization curve for a typical DC motor with a proper sketch.

[5 marks]

(b) A 4-pole, 1500 rpm lap wound (i.e no of current path = number of poles, a = p) DC shunt motor with total number of conductor, Z = 400 develops a mechanical torque, τ of 36.6056 N-m at an armature current of 45A. If the armature and field resistances are 0.1Ω and 120Ω respectively, determine the:

i. flux per pole,

[3 marks]

ii. sketch the equivalent circuit of the DC shunt motor,

[3 marks]

iii. input voltage, V_S,

[2 marks]

iv. input current, I_S.

[2 marks]

(Note: Induced EMF, $E_A = \frac{Zp}{2\pi a}\phi\omega_m$)

(c) No-load and blocked rotor tests conducted on a 220V, 4-pole, 50Hz, Y-connected induction motor yields the following results:

No-load test: 220V (line-to-line), 8.17A, 405W
Blocked rotor test: 25V (line-to-line), 27.9A, 920W

The stator DC resistance measurement gives voltmeter and ammeter readings of 14V and 28A respectively. Determine the parameters of the approximate equivalent circuit of this motor as shown in Figure Q3 if the design is class D (i.e. $X_S = X'_R$).

[10 marks]

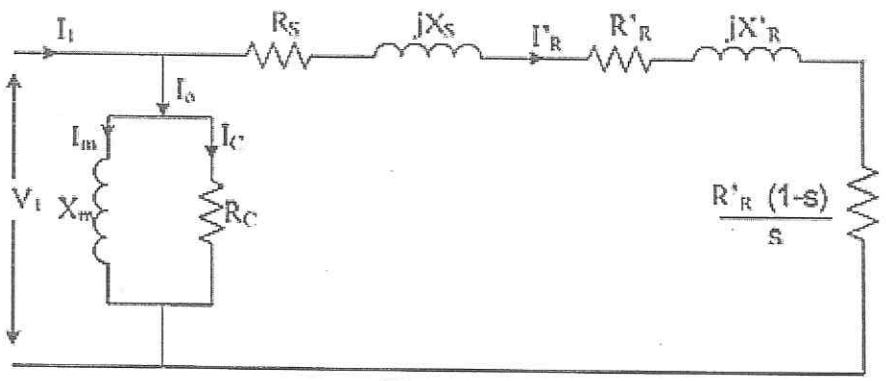

Figure Q3

Continued...

Question 4

(a) Figure Q4(a) shows the one-line diagram of a power system. The ratings of the components are listed as follows:

Generator, G:	120MVA, 24.4kV, $R = 20\ \%$, $X = 90\ \%$
Transformer, T1:	95MVA, 24.4/280kV, $R = 5\ \%$, $X = 12\ \%$
Transformer, T2:	75MVA, 320/13.8kV, $R = 5\ \%$, $X = 12\ \%$
Motor, M:	60MVA, 12kV, $R = 40\ \%$, $X = 80\ \%$

The transmission line has an impedance of $(15 + j45)\Omega$, and the static load impedance is $(2.75 + j3.25)\Omega$. A common base of 120MVA and 24.4kV at the generator side is selected for the system.

i. Calculate the base voltages and impedances in Regions 1, 2 and 3. [5 marks]

ii. Draw the impedance diagram of this power system, and label all the impedances in per-unit (p.u.). [8 marks]

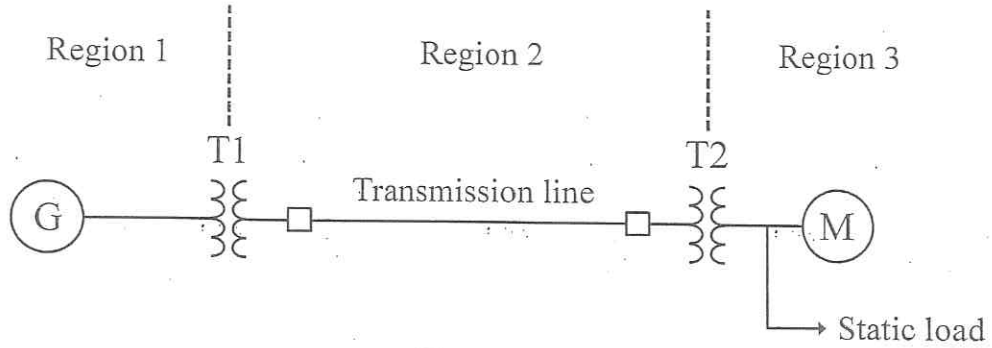

Figure Q4(a)

(b) Describe how overcurrent protection devices work. [3 marks]

Continued...

(c) Characteristic curves of the CO-8 relay (a typical time-delay overcurrent relay) are shown in Figure Q4(b).

i. The two relay settings shown in Figure Q4(b) are time dial setting and current tap setting. Define current tap setting. [2 marks]

ii. If an overcurrent relay remains in the blocking position and does not operate, what does this indicate? [2 marks]

iii. A CO-8 relay (with characteristic curves shown in Figure Q4B) has a time dial setting of 2 and a current tap setting of 6A. It is used with a 200:5 current transformer to protect a distribution system. Determine the relay current, plug setting multiplier (PSM) and relay operating time (in seconds) for a primary fault current of 600A. [5 marks]

CO-8 time-delay overcurrent relay characteristics (Courtesy of Westinghouse Electric Corporation)

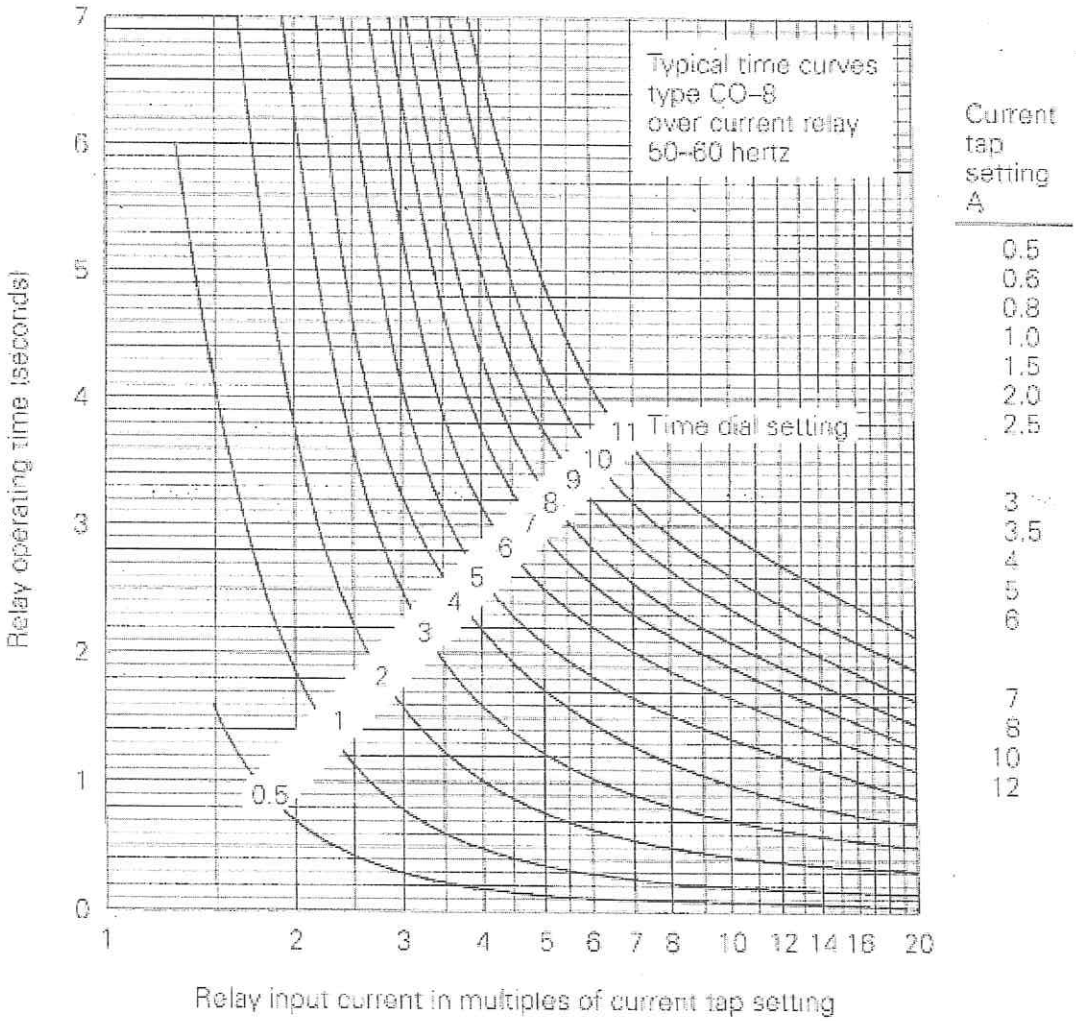

Figure Q4(b)

End of Question

APPENDIX

Magnetic Circuits

$$H = \frac{Ni}{l_c}$$
$$B = \mu H = \mu_0 \mu_r H$$
$$\phi = BA$$
$$\Re = \frac{l_c}{\mu A}$$
$$\mathcal{F} = Ni = \phi\Re = Hl_c$$
$$\mathcal{F} = ilB \sin\theta$$
$$e_{ind} = vlB \sin\theta_1 \cos\theta_2$$
$$P = \tau\omega$$

Three-Phase Circuits

Y-Connection: $I_L = I_\phi,\ V_L = \sqrt{3}V_\phi \angle 30°$

Δ-Connection: $V_L = V_\phi,\ I_L = \sqrt{3}I_\phi \angle -30°$

Δ-Y Transformations:

$$R_a = \frac{R_{ac}R_{ab}}{R_{ac} + R_{ab} + R_{bc}}$$
$$R_b = \frac{R_{ab}R_{bc}}{R_{ac} + R_{ab} + R_{bc}}$$
$$R_c = \frac{R_{bc}R_{ac}}{R_{ac} + R_{ab} + R_{bc}}$$

Y-Δ Transformations:

$$R_{ac} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_b}$$
$$R_{ab} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_c}$$
$$R_{bc} = \frac{R_aR_b + R_bR_c + R_cR_a}{R_a}$$

$$P_T = 3|V_\phi||I_\phi|\cos\theta = \sqrt{3}|V_L||I_L|\cos\theta$$
$$Q_T = 3|V_\phi||I_\phi|\sin\theta = \sqrt{3}|V_L||I_L|\sin\theta$$
$$S_T = 3|V_\phi||I_\phi| = \sqrt{3}|V_L||I_L|$$

Transformers

Turn ratio: $a = \frac{N_P}{N_S} = \frac{V_P}{V_S} = \frac{I_S}{I_P}$

Equivalent circuit (referred to primary):

$$V_s' = aV_S,\quad I_s' = \frac{I_S}{a}$$
$$R_s' = a^2R_S,\quad X_s' = a^2X_S,\quad Z_L' = a^2Z_L$$
$$R_{eqP} = R_P + a^2R_S,\quad X_{eqP} = X_P + a^2X_S$$

Equivalent circuit (referred to secondary):

$$V_P' = \frac{V_P}{a},\quad I_P' = aI_P$$
$$R_P' = \frac{R_P}{a^2},\quad X_P' = \frac{X_P}{a^2}$$
$$R_{eqS} = R_S + \frac{R_P}{a^2},\quad X_{eqS} = X_S + \frac{X_P}{a^2}$$

Short-Circuit Test

$$Z_{eq} = \frac{V_{SC}}{I_{SC}},\quad R_{eq} = \frac{P_{SC}}{{I_{SC}}^2}$$
$$X_{eq} = \sqrt{{Z_{eq}}^2 - {R_{eq}}^2}$$

Open-Circuit Test

$$R_C = \frac{{V_{OC}}^2}{P_{OC}},\quad S_{OC} = V_{OC}I_{OC}$$
$$Q_m = \sqrt{{S_{OC}}^2 - {P_{OC}}^2}$$
$$X_m = \frac{{V_{OC}}^2}{Q_m}$$

Voltage Regulation

$$VR = \frac{V_{NL} - V_{FL}}{V_{FL}} \times 100\%$$

Efficiency $\eta = \frac{P_{out}}{P_{in}} \times 100\%$

End of Paper